Draft Fiddlers Cove and Rands Harbor Embayment Systems Total Maximum Daily Loads for Total Nitrogen

(Control # 394.0)

COMMONWEALTH OF MASSACHUSETTS
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DRAFT
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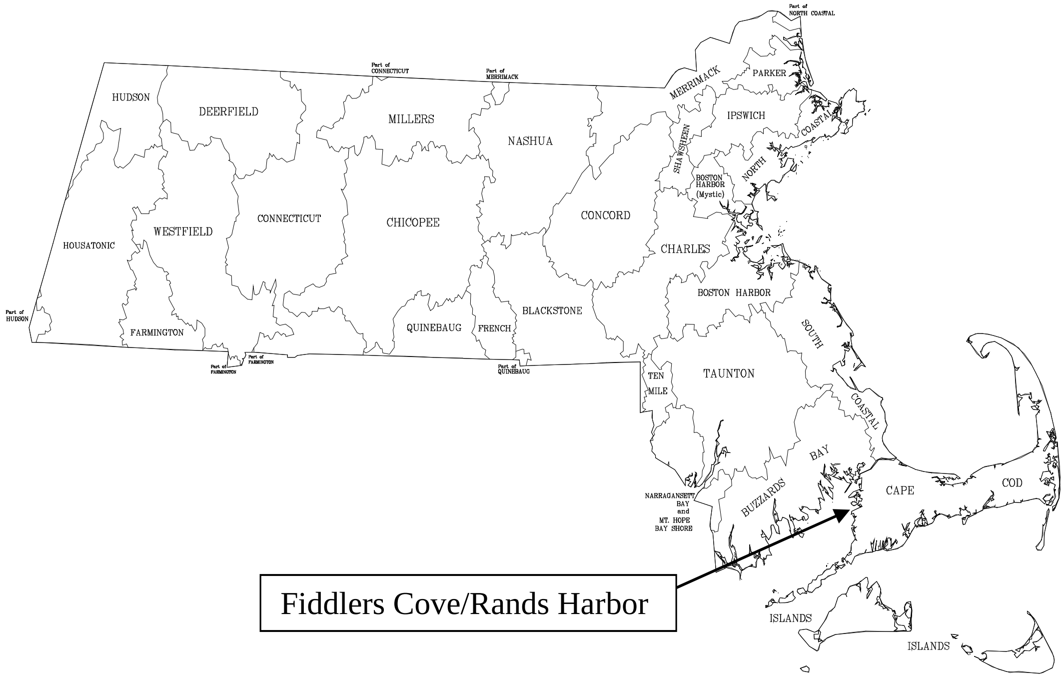


Key Feature:	Total Nitrogen TMDLs for Fiddlers Cove and Rands Harbor Embayment Systems
Location:	EPA Region 1, Towns of Falmouth, Bourne and Sandwich
Land Type:	New England Coastal
303d Listing:	Fiddlers Cove (MA95-79) and Rands Harbor (MA95-78) are listed in the MassDEP 2014 Integrated List of Waters as impaired for Nutrient/Eutrophication Biological Indicators.
Data Sources:	University of Massachusetts – Dartmouth/School for Marine Science and Technology (SMAST); US Geological Survey; Applied Coastal Research and Engineering, Inc.; Town of Falmouth; Buzzards Bay Program
Data Mechanism:	Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
Monitoring Plan:	Buzzards Bay Coalition’s Baywatcher Monitoring Program and the Town of Falmouth monitoring program (technical assistance from SMAST)
Control Measures:	Sewering, Storm Water Management, Freshwater Attenuation , Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a range of sources has added to the impairment of the environmental quality of the Fiddlers Cove and Rands Harbor Embayment Systems. Excessive N is indicated by:

- Undesirable increases in macro algae
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

With proper management of N inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

Coastal communities rely on clean, productive, and aesthetically pleasing marine and estuary waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings could result in an overabundance of macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of the Fiddlers Cove and Rands Harbor estuaries will be greatly reduced.

Sources of Nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - Natural background
    - Septic Systems
    - Runoff
    - Fertilizers
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Figures ES-A and Figure ES-B illustrate the percent contribution of all watershed sources of N and the controllable N sources to the estuary systems. Values are based on Table IV-2 and Figure IV-6 from the Massachusetts Estuaries Project (MEP) Technical Report. As evident, most of the present *controllable* load to these systems comes from septic systems.

Figure ES-A: Relative Contribution of All Watershed Nitrogen Sources (Uncontrollable and Controllable) in Fiddlers Cove

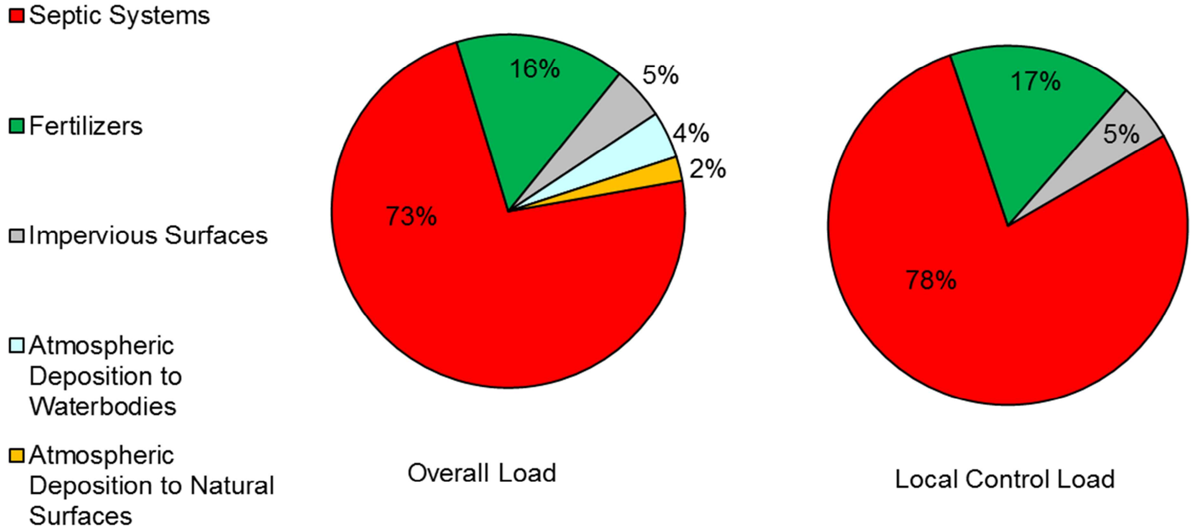
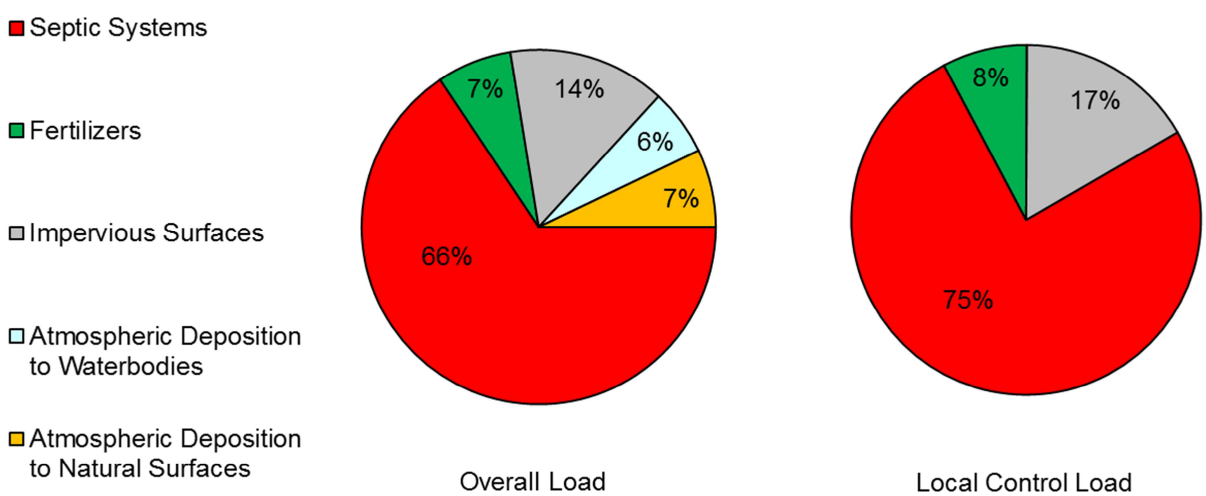


Figure ES-B: Relative Contribution of All Nitrogen Sources (Uncontrollable and Controllable) in Rands Harbor



Target Threshold N Concentrations and Loadings

Fiddlers Cove and Rands Harbor lie entirely within the town of Falmouth on Cape Cod, Massachusetts. The total attenuated N loadings (the quantity of N) from all sources to the Fiddlers Cove Estuarine System is 5.77 kg/day and to the Rands Harbor Estuarine System is 6.89 kg/day (Table ES-1, MEP Technical Report, Howes *et al* 2013). The concentrations of N measured at the monitoring stations ranged from 0.335-0.537 mg/L in Fiddlers Cove and 0.374-0.544 mg/L in Rands Harbor. This is the range of average annual means collected from one station in each harbor between 2000-2009, and reported in Table VI-1, Howes et al 2013 and included in Appendix B of this report.

In order to restore and protect these estuary systems, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below those that cause the observed environmental impacts. This N concentration will be referred to as the *target threshold N concentration*. The Massachusetts Estuaries Project (MEP) has determined that by achieving a N concentration of 0.50 mg/L at three sentinel stations, one located in the upper canal of Fiddlers Cove and one in each of the terminal basins of the north and south arms of Rands Harbor (see Figure 7), water quality and benthic habitat quality will be restored in these systems. The mechanism for achieving the target threshold N concentrations is to reduce the N loadings from the watersheds of these systems.

Based on the MEP sampling and modeling analyses and the Technical Report, the MEP study has determined that the Total Maximum Daily Load (TMDL) of N that will meet the target threshold N concentration of 0.50 mg/L is 4.76 kg/day in the Fiddlers Cove watershed and 5.13 kg/day in the Rands Harbor watershed. To meet these TMDLs this report recommends a reduction of 33 and 40% of the septic load for Rands Harbor (subwatersheds of the north and south arms, respectively) and a 38% reduction of the septic load from the Fiddlers Cove, upper canal subwatershed. This document presents the TMDLs for these water body systems and provides guidance to the watershed community of Falmouth on possible ways to reduce the N loadings to within the recommended TMDLs and protect the waters of these embayment systems. (There are small portions of Bourne and Sandwich that are located within the upper watershed to Fiddlers Cove and Rands Harbor. Note that this area is located within the Massachusetts Military Reservation and is either undeveloped or already served by sewers.)

Implementation

The primary goal of TMDL implementation will be lowering the concentrations of N by reducing the loadings from on-site subsurface wastewater disposal (septic) systems 33 – 40% in selected subwatersheds in these systems. However, there is a variety of loading reduction scenarios that could achieve the target threshold N concentrations. Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to this system. Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). Implementing BMPs to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to these systems. Methods for reducing N loadings from these sources are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies" which is available on the MassDEP website: http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html. The appropriateness of any of the alternatives will depend on local conditions and will have to be determined on a case-by-case basis using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208. Finally, growth within the community of Falmouth that would exacerbate the problems associated with N loadings should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters that are not meeting water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings of these pollutants of concern from all contributing sources that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the watershed town of Falmouth to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Fiddlers Cove and Rands Harbor embayment systems the pollutant of concern for these TMDLs (based on observations of eutrophication) is the nutrient nitrogen. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased so is the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton which impairs the healthy ecology of the affected water bodies.

The TMDLs for total N for Fiddlers Cove and Rands Harbor are based primarily on data collected, compiled and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST) Coastal Systems Program and Buzzards Bay Coalition's Baywatchers Monitoring Program as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2000 through 2009. This study period will be referred to as the "present conditions" in the TMDL report since it contains the most recent data available. The accompanying MEP Technical Report can be found at http://bit.ly/MassEstuariesProject. The MEP Technical Report presents the results of the analyses of the coastal embayment systems using the MEP Linked Watershed-Embayment N Management Model (Linked Model) (Howes *et. al* 2013). The analyses were performed to assist the watershed community with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space and harbor maintenance programs. A critical element of this approach is the assessment of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements and benthic community structure that was conducted on this embayment. These assessments served as the basis for generating a N loading threshold for use as a goal for watershed N management. The TMDLs are based on the site specific N thresholds generated for these embayments. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process in the watershed community of Falmouth.

Description of Water Bodies and Priority Ranking

Watershed Characterization

The MEP team has delineated a watershed area of approximately 2.4 square miles for the combined Fiddler's Cove and Rands Harbor estuarine systems. The delineated contributory watershed includes seventeen subwatersheds which were delineated for estimation of groundwater flows and nutrient export (Figure 1 in this report and Howes *et. al*, 2013, pg. 30). The MEP team has estimated a total groundwater flow of 1,792 m^3/day and 7,737 m^3/day for Fiddler's Cove and Rands Harbor, respectively.

In the both Fiddlers Cove and Rands Harbor watersheds , the predominant land use based on area is the public service land use, which accounts for 38% and 60%, respectively, of the watershed area in each embayment. The public land use is principally related to state owned property at the Massachusetts Military Reservation (MMR) but also includes municipal properties and other tax exempt properties. Residential landuse is the second largest landuse by area. It accounts for 32% of the watershed area of Fiddlers Cove and 23% of the Rands Harbor watershed area. The next highest land use type is undeveloped lands which accounts for 14% of the Fiddlers Cove watershed area and 10% Rands Harbor watershed area.

The developed regions of the watersheds to Fiddlers Cove and Rands Harbor are almost entirely within the town of Falmouth. The upper most portion of the watershed also falls within Sandwich and Bourne, however this portion of the watershed is mostly undeveloped. The upper watershed within the MMR (about 1/4 of watershed) is mainly undeveloped and what is developed is sewered and does not contribute a significant N load to the estuaries. The major stakeholder for management and restoration of Fiddlers Cove and Rands Harbor is the town of Falmouth.

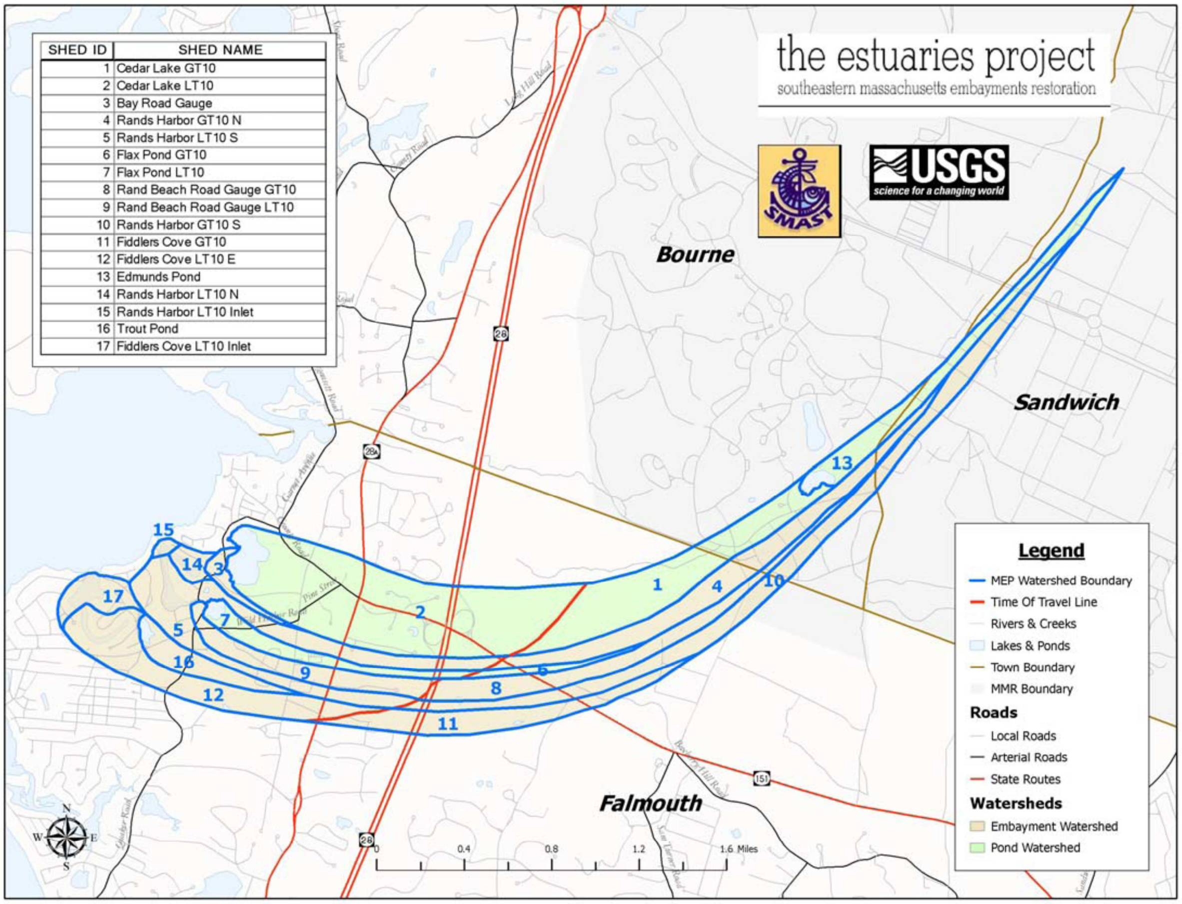

Figure 1: Watershed Delineations for Fiddlers Cove and Rands Harbor (excerpted Howes *et al* 2013, pg. 30)

Description of Waterbodies

The Fiddlers Cove and Rands Harbor embayments are located entirely within the town of Falmouth. These two embayments have a northern shore bounded by outer Megansett Harbor, which exchanges tidal waters with Buzzards Bay. Both Fiddlers Cove and Rands Harbor are part of the larger complex of the Megansett Harbor / Squeteague Harbor estuary. This larger overall estuary is comprised of three principal basins: an open water portion of the system directly connected to Buzzards Bay (outer Megansett Harbor), a more enclosed basin (inner Megansett Harbor) which feeds directly into an enclosed basin (Squeteague Harbor) via a narrow shallow channel. Fiddlers Cove and Rands Harbor are two small tributary embayments to outer Megansett Harbor (Figure 2).

The Fiddlers Cove and Rands Harbor embayments are presently relatively simple estuary systems with Rands Harbor being the more complex of the two, having one inlet but two distinct branches (East Branch and West Branch). The present inlet to Fiddlers Cove is armored and leads into a main basin that serves as a small mooring area for boats and supports a large marina. The main basin of the Fiddlers Cove system leads into a narrow terminal upper canal that extends landward towards Fiddlers Cove Road (Figure 2). The canal is fully armored and is an artificial feature of the system. At present, Fiddlers Cove does not receive direct stream discharge, with virtually all watershed input being through direct groundwater discharge.

Figure 2: Fiddlers Cove and Rands Harbor Embayment Systems (blue line represents watershed boundary)**.**

Similar to the adjacent Fiddlers Cove, Rands Harbor receives low nutrient water from Buzzards Bay via a single inlet that connects the system to outer Megansett Harbor. The inlet to Rands Harbor is armored to the east and leads to the confluence of two narrow branches, a north arm and a south arm, both of which have dredged channels and end in small terminal basins. Each terminal basin receives surface water discharge from its upper watershed via a small stream. The north arm stream originates in Cedar Lake whereas the south arm stream is sourced in Flax Pond (Figure 2). Both these streams are also likely to be slightly groundwater fed features in addition to receiving freshwater from their up-gradient ponds.

The present open water embayment structure of both Fiddlers Cove and Rands Harbor do not represent a natural estuary structure. Both are artificial open water embayments significantly altered by human activity over the past approximately 100 years. Both embayments were formed primarily as tidal salt marshes with associated tidal creeks as seen in 1880 and 1916 historical maps (Howes *et al* 2013, pg 124). Human activity gradually transformed these salt marsh dominated tidal creeks into more open water systems resembling embayments (Figure 3). The tidal wetlands were removed to increase the navigability of the systems and to create protected harbors, though portions of the upper reaches of Fiddlers Cove still supported bordering saltmarsh into the 1970's. At present almost all of the tidal wetlands along the shoreline of Fiddlers Cove have been removed and replaced with hard coastal structures (e.g. riprap). Although Rands Harbor was also constructed from tidal creeks, it still maintains significant fringing salt marsh areas, particularly in the southern branch. Based on the history of both these systems, they likely have not supported eelgrass over the past 60 years.

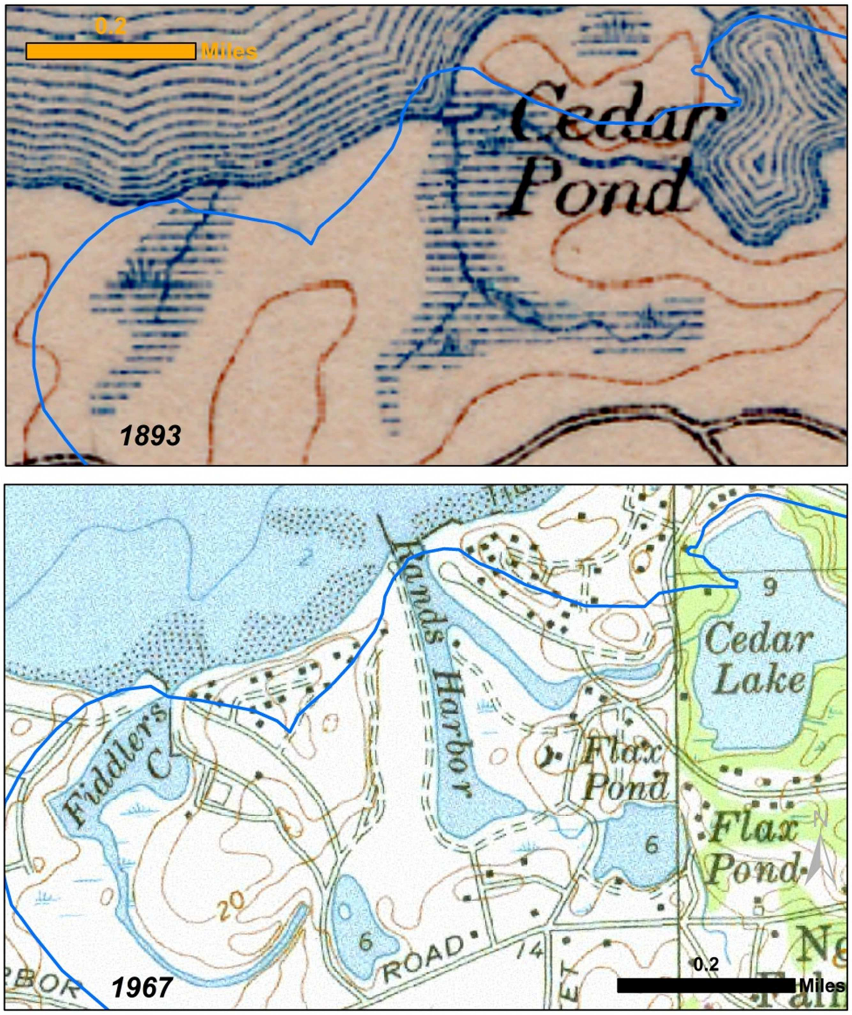

Figure 3: Historical Maps; 1893 and 1967 (MassGIS 2001 and 2007)

Fiddlers Cove and Rands Harbor both act as a mixing zone for terrestrial freshwater inflow and saline tidal flow from Buzzards Bay via outer Megansett Harbor, however, the salinity characteristics of the system varies with the volume of freshwater inflow as well as the effectiveness of tidal exchange with outer Megansett Harbor. Overall, the small freshwater contributing area and large tide range result in a relatively high average salinity (>27ppt) throughout much of Fiddlers Cove and Rands Harbor (>29 ppt and >27 ppt respectively).

Fiddlers Cove and Rands Harbor (but more so Fiddlers Cove) are important for recreational boating. The private marina that represents a large part of the boating activity in Fiddlers Cove has two main docks, which consists of piers with floats, and slips along a seawall. The marina operates a full service boat yard and boat fueling at the marina dock is available as is electricity. Pump-out facilities for boat waste are provided by the marina.

These embayments constitute an important component of the area's natural and cultural resources. The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline, they are popular regions for boating, recreation, and land development; and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores.

Complete descriptions of these embayment systems are presented in Chapters I and IV of the MEP Technical Report. A majority of the information presented here is drawn from this report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that Fiddlers Cove and Rands Harbor are impaired due to excess nutrients, low dissolved oxygen levels, elevated chlorophyll *a* levels, and benthic fauna habitat degradation.

In particular, Fiddlers Cove and Rands Harbor are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Fiddlers Cove and Rands Harbor are listed in the MA 2014 Integrated List of Waters as impaired for Nutrient/Eutrophication Biological Indicators (MassDEP 2015). Table 1 identifies the waterbodies that were observed to be impaired through the MEP analysis.

Table 1: Impaired Parameters for Fiddlers Cove and Rands Harbor

System Component	MassDEP Segment Number	MassDEP Segment Description	Class	2014 Integrated List Category	SMAST Impaired Parameter[1]	Size (acres)[1]
Fiddlers Cove	MA95-79	cove south off Megansett Harbor, Falmouth	SA	Nutrient/Eu-trophication Biological Indicators	Nutrients, Benthic Fauna, Dissolved Oxygen, Chlorophyll *a*	14.96
Rands Harbor	MA95-78	harbor south off Megansett Harbor, Falmouth	SA	Nutrient/Eu-trophication Biological Indicators	Nutrients, Benthic Fauna, Dissolved Oxygen, Chlorophyll *a*	11.65

[1] As determined by the MEP Fiddlers Cove and Rands Harbor Study and reported in the Technical Report (Howes *et al*, 2013)

Priority Ranking

The embayments addressed by this document have been determined to be "high priority" based on three significant factors: (1) the initiative that the Town of Falmouth has taken to assess the conditions of the entire embayment system; (2) the support of the town to restore Fiddlers Cove and Rands Harbor; and (3) the extent of impairment in Fiddlers Cove and Rands Harbor. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems and limits on the use of water resources. Observations are summarized in the Problem Assessment section below and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

Description of Hydrodynamics of the Fiddlers Cove and Rand Harbor Systems

Both Fiddlers Cove and Rands Harbor are fairly deep coastal embayments with average depths of 7.7 and 6.8 feet mean low tide (MLW) respectively. The MEP project has evaluated the tidal circulation and flushing characteristics of Fiddlers Cove and Rands Harbor using both direct measurements and the RMA-2 model, a well-established model for estuaries. The MEP project deployed three tidal gaging stations: one in each Fiddlers Cove and Rands Harbor and one in Megansett Harbor to evaluate tidal characteristics. Little tidal dampening was found between Megansett Harbor and Fiddlers Cove or Rands Harbor. In addition the phase delay of the main tidal constituent (lunar, twice per day tide, aka M2) was only approximately 12 minutes between Megansett Harbor and Fiddlers Cove while it was less than the measurement period of the tide gage recorders (10 minutes) for Rands Harbor. The MEP project also determined a system residence time of approximately one day for both embayments. Given these facts Howes *et. al* (2013) found the two systems are well flushed.

Problem Assessment

Water quality problems associated with development within the watershed result primarily from septic systems and from runoff, including fertilizers. The water quality problems affecting nutrient-enriched embayments generally include periodic decreases of dissolved oxygen, decreased diversity and quantity of benthic animals and periodic algae blooms as well as loss of eelgrass habitat (if the embayment historically supported eelgrass). In the most severe cases habitat degradation could lead to periodic fish kills, unpleasant odors and scums and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

Figure 4 shows how the population of Falmouth has increased from over five times what it was in 1940 (from about 6,000 to over 31,000 people in 2010). Increases in N loading to estuaries are directly related to increasing development and population in the watershed. The town of Falmouth does not have a centralized wastewater treatment system. This increase in population contributes to a decrease in undeveloped land and an increase in septic systems, runoff from impervious surfaces and fertilizer use. These unsewered areas contribute significantly to the system through transport in direct groundwater discharges to estuary waters as well as through surface water flows.

Coastal communities, including Falmouth, rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as commercial fin fishing and shell fishing. The continued degradation of these coastal embayments, as described above, will significantly reduce the recreational and commercial value and use of these important environmental resources.

Habitat and water quality assessments were conducted on these estuary systems based upon water quality monitoring data, time-series water column oxygen and chlorophyll *a* measurements and benthic community structure. The MEP evaluation of habitat quality supported by each area considers its natural structure and its ability to support eelgrass beds and the types of infaunal communities that they support (Table 2). These systems were determined to be fully representative of tidal embayments, as opposed to tidal rivers or salt marshes. As eelgrass beds could not be documented to exist, either historically or presently, the thresholds analysis for these systems is focused on restoration of their impaired infaunal animal habitats resulting in part from oxygen depletion and organic matter enrichment. The absence of historic eelgrass coverage in both Fiddlers Cove and Rands Harbor in part, stems from the fact that these are artificial embayments that have been significantly altered by human activity for decades.

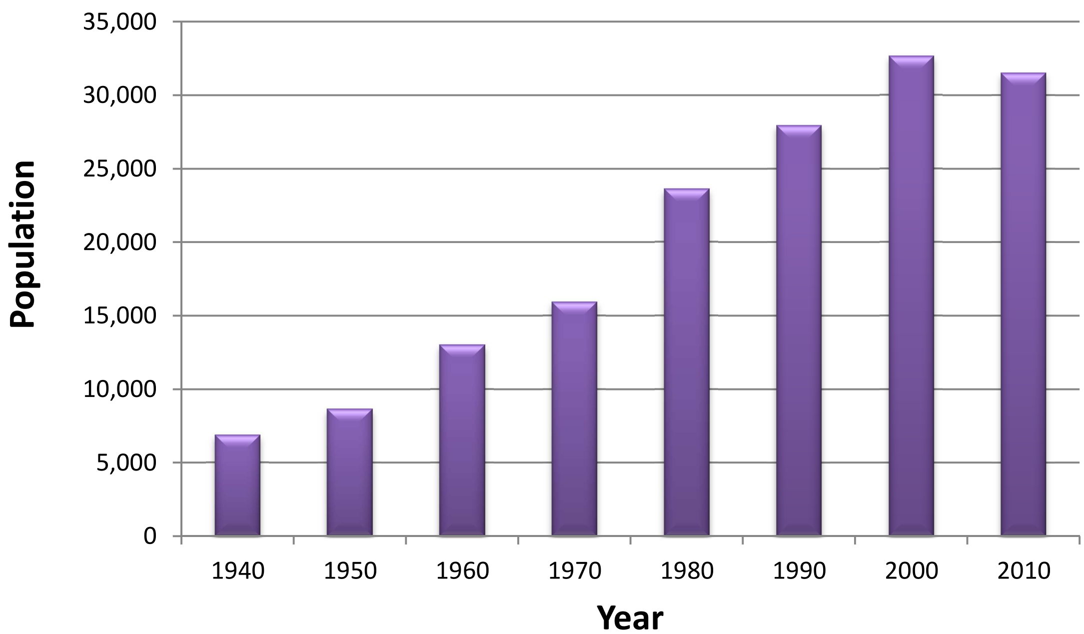

Figure 4: Resident Population for Falmouth
http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

The oxygen data is consistent with organic matter enrichment within Fiddlers Cove and Rands Harbor, and are further supported by elevated parallel measurements of chlorophyll *a*. The measured levels of oxygen depletion and enhanced chlorophyll *a* levels follows the spatial pattern of total nitrogen levels, and the parallel variation in these water quality parameters is consistent with watershed based nitrogen enrichment.

Overall, the infauna survey indicated that Fiddlers Cove presently supports low to moderately impaired benthic infaunal habitat. In the Rands Harbor system both the north and south arms are also exhibiting impaired benthic infaunal habitat, with the north arm more impaired than the south arm. It appears that organic deposition in these areas is the cause of the stress, consistent with the bottom water oxygen levels and phytoplankton biomass. In both of these systems there is a gradient in benthic animal habitat impairment with low to moderate impairment nearest the tidal inlet that increases landward. Total nitrogen levels within the upper canal of Fiddlers Cove and within the upper terminal basins of Rands Harbor were modeled by SMAST at 0.558 mg/L and 0.57 mg/L, respectively, which are levels generally found associated with a low to moderate level of impairment of benthic animal habitat in southeastern Massachusetts estuaries.

In summary, Fiddlers Cove and Rands Harbor are beyond their ability to assimilate nitrogen without impairment and are showing a moderate level of nitrogen enrichment, with generally moderate impairment of infaunal habitats.

Table 2: General Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in Fiddlers Cove and Rands Harbor (excerpted Howes *et. al*. 2013, pg. 136)

Health Indicator	**Fiddlers Cove**		**Rands Harbor**	
	Main Basin	Canal	East Branch	West Brach
Eelgrass Loss	Artificial open water basin, no historical evidence of eelgrass beds within this basin [NA]	Artificial open water basin, no historical evidence of eelgrass beds within this basin [NA]	Artificial open water basin, no historical evidence of eelgrass beds within this basin [NA]	Artificial open water basin, no historical evidence of eelgrass beds, but possibly some patches ca. 1950 [NA]
Dissolved Oxygen Depletion	mooring oxygen <5mg/L 26%, <4mg/L 2% of time, generally 4-7 mg/L, daily excursion ~2.5 mg/L, WQMP: >5 mg/L 100%, >6 mg/L 94%of 158 samples [**MI**]	mooring oxygen <6mg/L 44%, <5mg/L 8% of time, periodically to 4mg/L, daily excursion ~2.5 mg/L [**MI**]	mooring oxygen >6mg/L >75, periodically to 5mg/L, daily excursion ~2.5 mg/L; WQMP South Branch: >5mg/L 95%, >6mg/L 81%, 4-5 mg/L 4%, 3.5-4mg/L 1%, of 195 samples, minimum = 3.5 mg/L [**H/MI**]	mooring oxygen >6mg/L >75, periodically to 5mg/L, daily excursion ~2.5 mg/L; WQMP South Branch: >5mg/L 95%, >6mg/L 81%, 4-5 mg/L 4%, 3.5-4mg/L 1%, of 195 samples, minimum = 3.5 mg/L [**H/MI**]
Chlorophyll *a*	Levels moderate for a coastal basin, mooring average 10.5 ug L-1, >10ug L-1 44% of record; blooms 20-30 ug L-1; WQMP long-term average 6.1 ug L-1, <10 ug L-1 89% of 40 samples. [**MI**]	Levels moderate/high, mooring average 15.2 ug L-1, >10ug L-1 74% of record; blooms >20 ug L-1 [**MI/SI**]	Levels low/moderate for a coastal basin, averaging 6.2 ug L-1, <5 ug L-1 44% and <10 ug L-1 85% of record; blooms ~15 ug L-1. [**H/MI**]	Levels moderate for a coastal basin, mooring average 8.3 ug L-1, >5 ug L-1 75%, >10ug L-1 25% of record; blooms 15-20 ug L-1; WQMP long-term average 8.8 ug L-1 [**MI**]
Benthic Fauna	moderate numbers of individuals, species (21), high diversity (>3) and Evenness (>0.7), dominated by non-stress indicator species with crustaceans and mollusks, some deep burrowers; gradient in habitat quality: highest near inlet lowest near mouth of Canal [**H/MI**]	Moderate numbers of individuals, species (19), diversity (2.8) and Evenness (~0.7), some stress indicator species but with crustaceans and mollusks, some deep burrowers [**MI**]	Low numbers of species, moderate number of individuals, low diversity (H':2.3) consistent with the organic rich sediments and periodic D.O. depletion to <4 mg/L. [**MI/SI**]	Upper reach: moderate numbers of individuals, moderate to high species (24), diversity (3.7) and Evenness (>0.7), with crustaceans and mollusks, some deep burrowers. [**MI**]
Macroalgae	Drift algae generally absent, some small patches of attached Codium [**H**]	Drift algae generally absent, some small patches of attached Codium [**H**]	Drift algae sparse to medium density patches over very soft organic rich muds [**H/MI**]	Sparse filamentous green algae with some attached Codium, sands and mud [**H**]
Overall Heath	Benthic infaunal animal communities are moderately diverse and productive with non-stress indicator species and some deep burrowers, but lower quality in the inner region. The level of impairment is consistent with infauna indicators, moderate chlorophyll & periodic DO to 4 mg/L, habitat quality gradient from inlet to mouth of Canal [**H/MI**]	Benthic infaunal animal communities are moderately diverse and productive with non-stress indicator species and some deep burrowers, but increased impairment over main basin. Moderate Impairment is consistent with infauna indicators, moderate/high chlorophyll & periodic DO to 4 mg/L and organic enrichment of the sediments [**MI**]	Benthic infaunal animal communities are moderately diverse and productive with non-stress indicator species and some deep burrowers, but increased impairment over main basin. Moderate Impairment is consistent with infauna indicators, moderate/high chlorophyll & periodic DO to 4 mg/L and organic enrichment of the sediments [**MI**]	Generally high quality benthic habitat in the upper reach but impaired habitat in the lower reach (which resembles the north branch). Animal communities consistent with the generally high DO with periodic depletion and moderate chlorophyll levels, sediments are sand in the upper reach and soft organic [**MI**] enriched muds in the lower reach.

H - Healthy habitat conditions, **MI** – Moderately Impaired, **SI** – Significantly Impaired - considerably and appreciably changed from normal conditions, **SD** – Severely degraded These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators" December 22, 2003. http://www.mass.gov/eea/docs/dep/water/resources/n-thru-y/nitroest.pdf

Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the town of Falmouth, as in most marine and coastal waters, the limiting nutrient is N. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions including the severe impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

The embayments addressed in this TMDL report have had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the town of Falmouth, The Buzzards Bay Program, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

Figures 5a and 5b illustrate the major controllable watershed sources of N to the Fiddlers Cove and Rands Harbor estuary systems (Table IV-3, Howes *et al*, 2013). Most of the controllable sources of N affecting these waterbodies originates from on-site subsurface wastewater disposal systems (septic systems). The level of "controllability" of each source, however, varies widely, as shown in Table 3:

Table 3: Sources of Nitrogen and their Controllability

Nitrogen Source	Degree of Controllability at Local Level	Reasoning
Atmospheric deposition to the estuary surface	Low	It is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible. Local control although helpful is not adequate.
Atmospheric deposition to natural surfaces (forests, fields, freshwater bodies) in the watershed	Low	Atmospheric deposition (loadings) to these areas cannot adequately be controlled locally. However, the N from these sources might be subjected to enhanced natural attenuation as it moves toward the estuary.
Fertilizer	Moderate	Lawn and golf course fertilizer and related N loadings can be reduced through BMPs, bylaws and public education.
Septic system	High	Sources of N can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing N-reducing on-site wastewater treatment systems.
Sediment	Low	N loadings are not feasibly controlled on a large scale by such measures as dredging. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. In addition, increased dissolved oxygen will help keep N from fluxing.
Stormwater runoff from impervious surfaces	Moderate	This nitrogen source can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education. Stormwater NPDES permit requirements help control stormwater related N loadings in designated communities.

Cost/benefit analyses will have to be conducted on all possible N loading reduction methodologies in order to select the optimal control strategies, priorities and schedules.

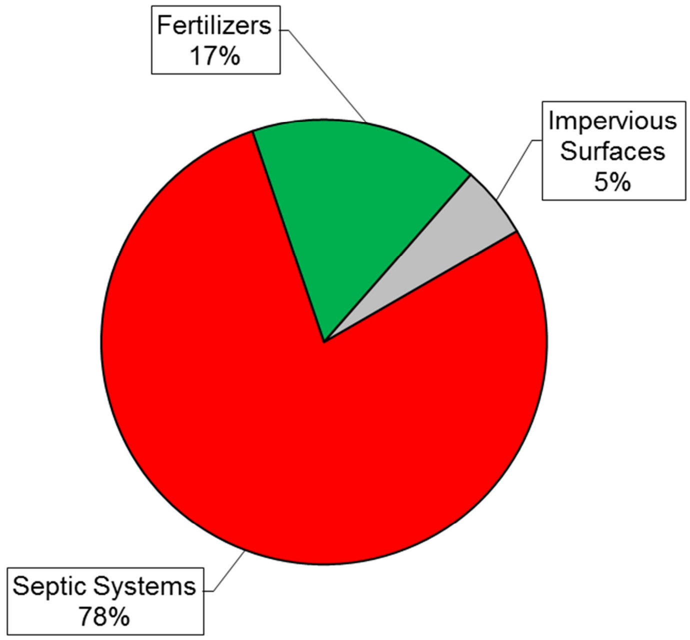

Figure 5a: Percent Contribution of Controllable Nitrogen Sources to Fiddlers Cove

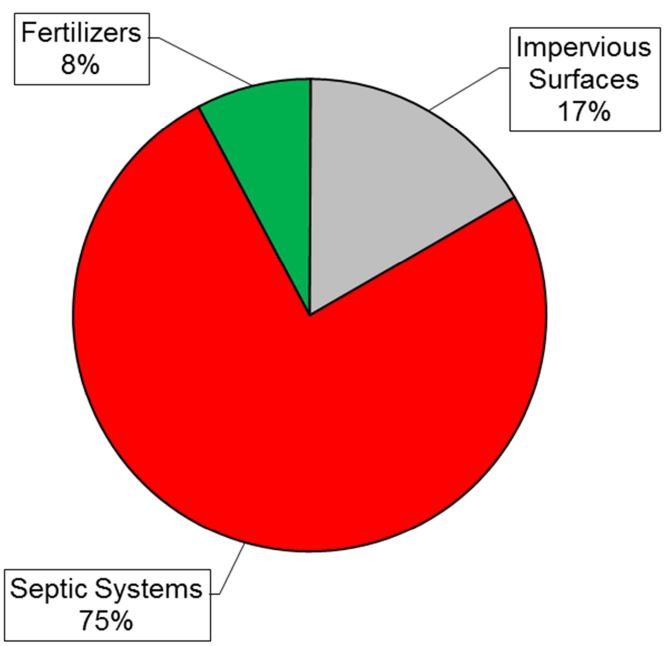

Figure 5b: Percent Contribution of Controllable Nitrogen Sources to Rands Harbor

Description of the Applicable Water Quality Standards

The water quality classifications of the saltwater portions of Fiddlers Cove and Rands Harbor are SA (all surface waters subject to the rise and fall of the tide), and any freshwater portions of the systems are classified as B. Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, and excess plant biomass and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) (MassDEP, 2007) contain descriptions of coastal and marine classes and numeric criteria for dissolved oxygen but have only narrative standards that relate to the other variables. The narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth are such that "all surface waters shall be free of nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed site specific criteria developed in a TMDL or otherwise, established by the department" (MassDEP 2007). A more thorough explanation of applicable standards can be found in Appendix A.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the EPA in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (Environmental Protection Agency, 2001). The Guidance Manual notes that lakes, reservoirs, streams and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters tend to have unique characteristics and development of individual water body criteria is typically required.

Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each embayment. Physical (Chapter V), chemical and biological (Chapters IV, VII, and VIII) data were collected and evaluated.
The primary water quality objective was represented by conditions that:

1) Prevent harmful or excessive algal blooms;

2) Restore and preserve benthic communities;

3) Maintain dissolved oxygen concentrations that are protective of the embayment aquatic life.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- Requires site specific measurements within the watershed and each sub-embayment;
- Uses realistic “best-estimates” of N loads from each land-use (as opposed to loads with built-in “safety factors” like Title 5 design loads);
- Spatially distributes the watershed N loading to the embayment;
- Accounts for N attenuation during transport to the embayment;
- Includes a 2D or 3D embayment circulation model depending on embayment structure;
- Accounts for basin structure, tidal variations, and dispersion within the embayment;
- Includes N regenerated within the embayment;
- Is validated by both independent hydrodynamic, N concentration, and ecological data;
- Is calibrated and validated with field data prior to generation of “what if” scenarios.

The Linked Model has been applied previously to watershed N management in numerous embayments thus far throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment becomes a N management-planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Also, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries.
It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP’s Linked Model process.

The Linked Model provides a quantitative approach for determining an embayment's (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation and recycling and variations in tidal hydrodynamics (Figure I-4 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

- Monitoring - multi-year embayment nutrient sampling;

• Hydrodynamics;
- Embayment bathymetry (depth contours throughout the embayment)
- Site-specific tidal record (timing and height of tides)
- Water velocity records (in complex systems only)
- Hydrodynamic model

• Watershed N Loading;
- Watershed delineation
- Stream flow (Q) and N load
- Land-use analysis (GIS)
- Watershed N model

• Embayment TMDL – Synthesis;
- Linked Watershed-Embayment N Model
- Salinity surveys (for linked model validation)
- Rate of N recycling within embayment
- Dissolved oxygen record
- Chlorophyll *a* record
- Macrophyte surveys
- Eelgrass and Infaunal surveys

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific embayments, for the purpose of developing target N loading rates, includes:

1) Selecting one or two stations within the embayment system located close to the inland-most reach or reaches which typically have the poorest water quality within the system. These are called "sentinel" stations;

2) Using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) Running the calibrated water quality model using different watershed N loading rates to determine the loading rate that will achieve the target threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold N concentration and the present watershed N load represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL.
Two outputs are related to N **concentration**:

- The present N concentrations in the sub-embayments;
- Site-specific target threshold N concentrations.

Two outputs are related to N **loadings:**

- The present N loads to the sub-embayments;
- Load reductions necessary to meet the site specific target threshold N concentrations.

In summary, if the water quality standards are met by reducing the N concentration (and thus the N load) at the sentinel station(s), then the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows.

Nitrogen Concentrations in the Embayment

1) Observed "present" conditions:

Table 4 presents the average concentrations of N measured in Fiddlers Cove and Rands Harbor from 2000 – 2009 as monitored by the Coalition for Buzzards Bay, BayWatcher Water Quality Monitoring Program and SMAST. The overall means and standard deviations of the averages are presented in Appendix B (taken from Table VI-1 of the MEP Technical Report). Water quality sampling stations are shown in Figure 7 below. The approximate location of the three sentinel stations are noted as red dots.

2) Modeled site-specific target threshold N concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. This is called the *target threshold nitrogen concentration.* Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific target threshold N concentrations by using the specific physical, chemical and biological characteristics of each embayment system.

Table 4: Present Nitrogen Concentrations and Sentinel Station Target Threshold Nitrogen Concentrations for Fiddlers Cove and Rands Harbor

Sub-Embayment	Station	Range of Annual Means [1]	**Mean[1]** (mg/L N)	Standard Deviation	Number Samples	Target Threshold Nitrogen Concentration (mg/L)
Rands Harbor	RH1	0.374-0.544	0.436	0.092	38	0.50[2]
Fiddlers Cove	FC1	0.322-0.537	0.414	0.098	38	0.50[3]
Buzzards Bay	CBB1		0.301	0.044	13	

1 Mean values are calculated as the average of the separate yearly means. Data collected in the summers of 2000 through 2009.
2 Target threshold N concentration set for each upper terminal basin of Rands Harbor (see Figure 7)
3 Target threshold N concentration set for the upper canal of Fiddlers Cove (see Figure 7)

Water quality monitoring stations, RH1 and FC1, are located near the mouths of the harbors where mixing with the cleaner waters of Buzzards Bay occurs. The sentinel stations as shown on Figure 7, are located higher up in the watershed, further from Buzzards Bay. Water quality modeling (Howes et al 2013, Figure VI-4) predicted higher average total N concentrations further from Buzzards Bay. The target threshold nitrogen concentrations for the embayments listed in Table 4 were determined as follows:

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout an embayment system, is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target threshold nitrogen concentration are determined, the MEP study modeled nitrogen loads from the watershed until the targeted nitrogen concentration was achieved.

Determination of the critical nitrogen threshold for maintaining high quality habitat within the Fiddlers Cove and Rands Harbor embayments is based primarily upon the nutrient and oxygen levels and current benthic community indicators, as there is no history of eelgrass colonization of these basins. Both Fiddlers Cove and Rands Harbor are exhibiting moderate impairment of benthic animal habitat coincident with documented levels of oxygen depletion and enhanced chlorophyll *a* levels throughout their tidal reaches. The spatial distribution of habitat quality and associated oxygen and chlorophyll *a* levels also parallels the gradient in water column total nitrogen levels within these estuaries with greater impairment in the upper versus lower reaches. All of these indicators support the conclusion that both systems are beyond their nitrogen thresholds (i.e. the level of nitrogen a system can tolerate without impairment).

Figure 6: Water Quality Sampling Stations in Fiddlers Cove and Rands Harbor
(Sentinel stations noted as red dots, excerpted from Howes *et. al* 2013, pg 97.)

Sentinel stations were established within each estuary for development of nitrogen threshold targets that when met will restore benthic animal habitat throughout the tidal reaches. Since nitrogen levels are highest in the upper reaches of each system the sentinel station for Fiddlers Cove was placed within the upper canal and in Rands Harbor in the terminal basins of each arm. Rands Harbor requires two sentinel stations, since the arms have different watersheds, stream inputs and sediment characteristics (See Figure 6). As there are no long-term water quality monitoring stations located at or near these three sites, the water quality model was used to determine the present total nitrogen levels at each sentinel station under present loading conditions in order to refine nitrogen threshold development (Section VI of the MEP Technical Report).

Using this approach, total nitrogen levels within the upper canal of the Fiddlers Cove is predicted to be 0.56 mg/L and within both the upper terminal basins of Rands Harbor is predicted to be 0.57 mg/L (Table VI-6, Howes *et al* 2013). These TN levels are comparable to other estuarine systems throughout the region that show similar levels of oxygen depletion, organic enrichment and moderately impaired benthic animal habitat. Given that in numerous estuaries it has been previously determined that 0.500 mg/L TN is the upper limit to sustain unimpaired benthic animal habitat (Eel Pond, Parkers River, upper Bass River, upper Great Pond, upper Three Bays) this level is deemed most appropriate for restoration of the basins comprising Fiddlers Cove and Rands Harbor. Watershed management to meet these restoration thresholds for benthic animal habitat is the focus of the nitrogen management threshold analysis.

The target threshold N concentration for an embayment represents the average water column concentration of N that will support the habitat quality and dissolved oxygen concentrations being sought. The water column N level is ultimately controlled by the integration of the watershed N load, the N concentration in the inflowing tidal waters (boundary condition), and dilution and flushing via tidal flows. The water column N concentration is modified by the extent of sediment uptake and/or regeneration and by direct atmospheric deposition.

Target threshold N concentrations in this study were developed to restore or maintain SA waters or high habitat quality. In this system, high habitat quality was defined as overall diverse benthic animal communities and dissolved oxygen levels that would support Class SA waters.

Nitrogen loadings to the embayment

1) Present Loading rates:
In the Fiddlers Cove and Rands Harbor systems overall, the highest N loading from ***controllable*** sources is from on-site wastewater treatment systems (See Figures 5a and 5b). The MEP Technical Report calculates that septic systems account for 78% and 75% of the controllable N load to Fiddlers Cove and Rands Harbor, respectively. Other sources include fertilizers (5% to Fiddlers and 8% to Rands), and runoff from impervious surfaces (17% to both systems). The MEP study determined that sediments contributed 22% of the nitrogen load to Fiddlers Cove and 9% to Rands Harbor. Atmospheric nitrogen deposition to the estuary and watershed surface area ranged from 12% in Rands Harbor to 5% in Fiddlers Cove. Nitrogen from sediments and atmospheric deposition is considered uncontrollable (Figures ES-A and ES-B).

A subwatershed breakdown of N loading by source is presented in Table 5. The information on which Table 5 is based can be found in Table ES-1 of the MEP Technical Report (Howes *et al* 2013).

As previously indicated, the present N loadings to these systems must be reduced in order to restore the impaired conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required that will achieve the target threshold N concentrations.

2) Nitrogen loads necessary for meeting the site-specific target threshold N concentrations:
Table 6 lists the present watershed N loadings to the Fiddlers Cove and Rands Harbor estuary systems and the percent watershed load reductions necessary to achieve the target threshold N concentration at the sentinel stations (see following section). The watershed delineations which correspond with the system components in the Table 6 nitrogen analysis can be found in Figure 7.

Table 5: Present Attenuated Nitrogen Loadings to the Fiddlers Cove and Rands Harbor Systems *

Embayment System	Present Land Use Load N[1] (kg/day)	Present Attenuated Septic System Load N (kg/day)	Present Total Attenuated Watershed Load N[2] (kg/day)	Direct Atmospheric Deposition N[3] (kg/day)	Present Net Benthic Flux N (kg/day)[4]	Total N Load from All Sources[5] (kg/day)
Rands Harbor	1.55	4.53	6.07	0.14	0.68	6.89
Fiddlers Cove	1.00	3.33	4.33	0.18	1.25	5.77
Total	2.55	7.86	10.4	0.32	1.93	12.66

[1]Composed of non-wastewater loads, e.g. fertilizer, runoff, atmospheric deposition to lakes and natural surfaces
[2] Includes fertilizer, runoff, natural background and septic system inputs
[3] Atmospheric deposition to the estuary surface only
[4] Nitrogen loading from sediments
[5] Composed of fertilizer, runoff, septic system inputs, atmospheric deposition and benthic nitrogen input
*From Table ES-1 MEP Technical Report (Howes *et al*, 2013).

Table 6: Present and Targeted Watershed Nitrogen Loading Rates and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loadings*

System Component	Present Attenuated Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	Percent watershed reductions needed to achieve target threshold loads
Rands Inlet	0.01	0.01	0%
Rands East Branch	2.50	1.82	-27%
Rands West Branch	3.56	2.57	-28%
Rands Harbor Total	6.07	4.41	-27%
Fiddlers Main	0.89	0.89	0%
Fiddlers Canal	3.44	2.48	-28%
Fiddlers Cove Total	4.33	3.37	-22%
Combined Total	10.40	7.78	-25%

[1] Composed of septic, fertilizer and runoff loadings
[2] Target threshold watershed load is the N load from the watershed (including natural background) needed to meet the target threshold N concentrations identified in Table 4, above.
*From Tables ES-2 and VIII-3 in the MEP Technical Report

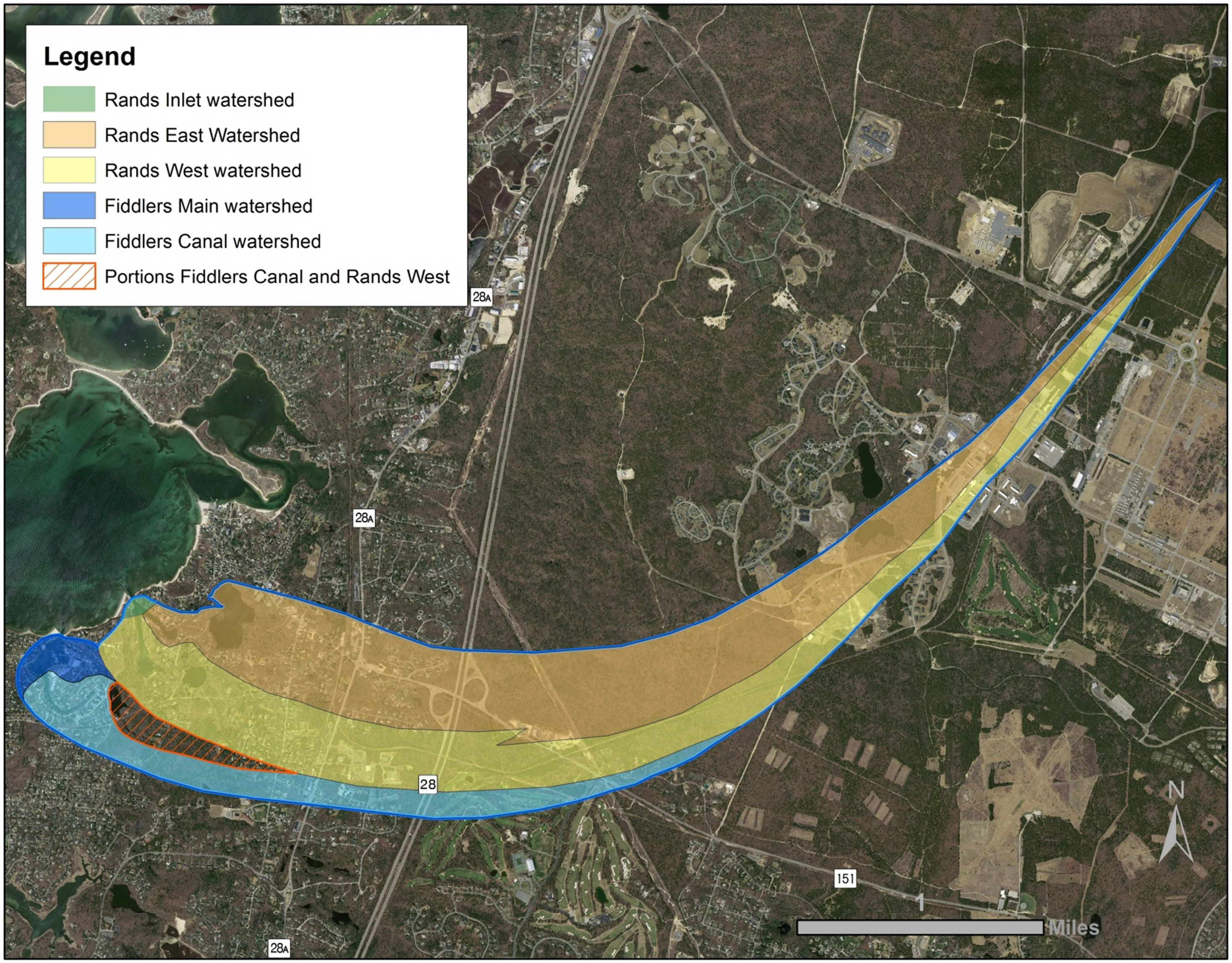

Figure 7: Fiddlers Cove and Rands Harbor Estuarine System Component Watersheds

It is very important to note that load reductions can be produced through a variety of strategies, including reduction of any or all sources of N, increasing the natural attenuation of N within the freshwater systems, and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). This scenario establishes the general degree and spatial pattern of reduction that will be required for restoration of the N impaired portions of these systems. The town of Falmouth should take any reasonable actions to reduce the controllable N sources.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuary ecosystem, including benthic macroinvertebrates, in this case the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDLs for Fiddlers Cove and Rands Harbor are aimed at establishing the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass as the primary indicator (if appropriate), as well as dissolved oxygen, chlorophyll *a* and benthic infauna.

The TMDL can generally be defined by the equation: ***TMDL = BG + WLAs + LAs + MOS***

Where:

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

Background Loading

Natural background N loading is included in the loading estimates, but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Waste Load Allocations

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater such as discharges from regulated wastewater treatment facilities and CSOs. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater also be included in the waste load component of the TMDL. In the Fiddlers Cove and Rands Harbor watersheds there are no NPDES regulated point source discharges with the exception of stormwater.

For purposes of the Fiddlers Cove and Rands Harbor TMDLs, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod and the Islands was never undertaken prior to the MEP study and used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater may be discharged directly to surface waters through outfalls. In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 feet from the shoreline would be directly discharged into surface waters. Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about stormwater collection systems on Cape Cod.

The estimated waste load allocation (WLA) was based on an assumption that runoff from all impervious surfaces within 200 feet of the shoreline discharges directly to the waterbodies. In Fiddlers Cove, this calculated load is 1.87% of the total N load or 0.08 kg/day as compared to the overall N load of 4.44 kg/day to the watershed. In Rands Harbor, the calculated waste load is 0.38% of the total N load or 0.03 kg/day as compared to the overall N load of 6.81 kg/day to the watershed (see Appendix C for details). This conservative load is obviously negligible when compared to other sources.

Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of Fiddlers Cove and Rands Harbor the locally controllable nonpoint source N loadings are from on-site subsurface wastewater disposal systems (septic systems) and other land uses (which include fertilizers and storm-water runoff (except from impervious cover within 200 ft of the waterbody which is defined above as part of the waste load). Figures 5a and 5b (above) and Figures 8a and 8b (below) clearly illustrate that septic systems are the most significant portion of the controllable N load (3.3-4.5 kg N/day). The N load from fertilizers and runoff is much less in each system (0.71 and 0.47 kg N/day for fertilizers and 0.22 and 1.0 kg N/day for stormwater in Fiddlers and Rands, respectively, as excerpted from Table IV-3 in the MEP Technical Report). In addition, there are nonpoint sources of N from sediments, natural background and atmospheric deposition that are not feasibly controllable.

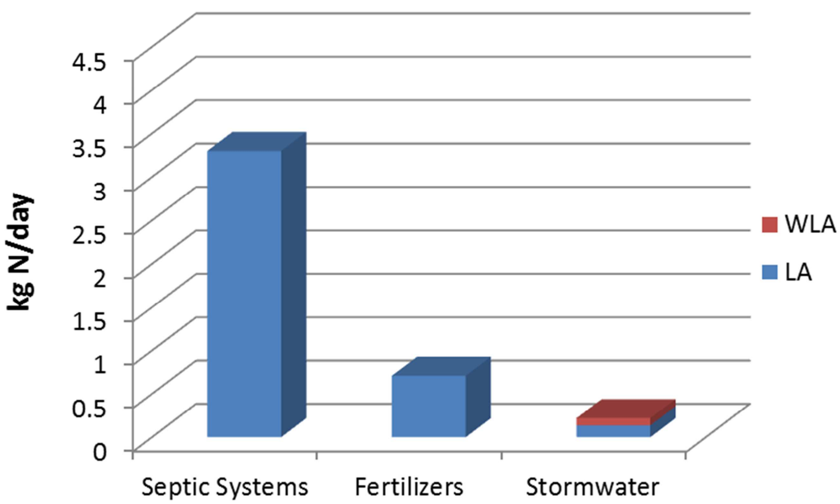

Figure 8a: Fiddlers Cove Locally Controllable N Sources

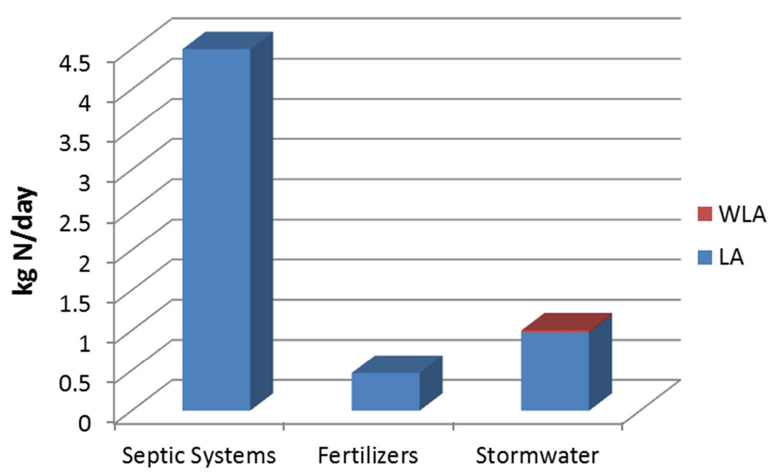

Figure 8b: Rands Harbor Locally Controllable N Sources

Generally, storm-water that is subject to the EPA Phase II Program is considered a part of the waste load allocation, rather than the load allocation. Chapters IV, V, and VI, of the MEP Technical Report, on Cape Cod and the Islands document that the vast majority of storm-water percolates into the aquifer and enters the embayment system through groundwater, thus defining the stormwater in pervious areas to be a component of the nonpoint source load allocation. As discussed above, even though there are measurable directly connected impervious areas in these systems, the wasteload allocation for stormwater was determined to be insignificant when compared to the overall controllable N load. Accordingly, this TMDL accounts for stormwater and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies.

The sediment loading rates incorporated into the TMDL are lower than the existing benthic input listed in Table 5 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments and therefore, over time, reductions in loadings from the sediments will occur. Benthic N flux is a function of N loading and particulate organic N (PON).

Projected benthic fluxes are based upon projected PON concentrations and watershed N loads and are calculated by multiplying the present N flux by the ratio of projected PON to present PON using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: $PON\ projected = (R_{load})\ (D_{PON}) + PON_{present\ offshore}$

When: $R_{load} = (projected\ N\ load) / (Present\ N\ load)$

And: D_{PON} is the PON concentration above background determined by:

$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$

The benthic fluxes modeled for Fiddlers Cove and Rands Harbor are reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to Buzzards Bay (boundary condition). The benthic flux input to each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load.

The loadings from atmospheric sources incorporated into the TMDL however, are the same rates presently occurring because, as discussed above, local control of atmospheric loadings is not considered feasible.

Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)].The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. The EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Fiddlers Cove and Rands Harbor Estuarine System TMDLs is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. In this context, "direct groundwater discharge" refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams, which receive much of their water from groundwater flow. Nitrogen from the upper watershed regions, which travels through ponds or wetlands, almost always enters the embayment via stream flow, and is directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been >95%. Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

In the case of N attenuation by freshwater ponds, attenuation is derived from measured N concentrations, pond delineation, and pond bathymetry. In the Rands Harbor Estuarine System, a small freshwater pond named Cedar Lake discharges to the head of the east branch of Rands Harbor via an un-named creek. Flax Pond, flows into the west branch of the Rands Harbor, also through an un-named creek. Water quality and flow monitoring of the outlet from Cedar Lake indicated a 19% reduction in total N that was attributed to biological uptake by plants. Monitoring of the un-named creek flowing out of Flax Pond did not indicate attenuation of N in Flax Pond. Flax Pond is shallow and acts more like a bog. There are no significant surface water discharges associated with Fiddlers Cove Estuarine System.

Similarly, the water column N validation dataset was also conservative. The model is validated to measured water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the predicted reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions (1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel stations and target threshold N concentrations. The sites for sentinel stations were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentration. The sentinel stations for Fiddlers Cove and Rands Harbor were chosen with the intent of restoring benthic infaunal habitat throughout the estuary systems. Meeting the target threshold N concentrations at the sentinel stations will result in reductions of N concentrations in the rest of the system.

3. Conservative approach

The target loads were based on tidally averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides and therefore this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a nonpoint source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety

In addition to the margin of safety within the context of setting the N threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these embayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the embayment are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense since it is difficult to control non-point sources of N on a seasonal basis and N sources can take considerable time to migrate to impacted waters.

Implementation Plans

The critical element of this TMDL process is achieving the sentinel station specific target threshold N concentrations presented in Table 4 above that are necessary for the restoration and protection of water quality and benthic habitat within Fiddlers Cove and Rands Harbor. In order to achieve these target threshold N concentrations, N loading rates must be reduced throughout the harbor embayment system.

Septic Systems:
As shown in Table 7 below, for the Fiddlers Cove system the TMDL was calculated by projecting a 38% reduction in locally controllable septic systems in the subwatershed of upper Fiddlers Cove (or Fiddlers Canal). For the Rands Harbor system septic reductions were applied to the subwatersheds of the east and west arm sub-embayments (33% and 40%, respectively).

Table 7: Comparison of Present Modeled Septic Loads to Modeled Septic Loads Required to Meet the Threshold N Concentrations for Each Sub-embayment

System Component	Present Septic N Load (kg N/day)	Threshold Septic load (kg N/day)	Threshold Septic Load % Change
Rands Inlet	0.01	0.01	0%
Rands East Branch	2.04	1.37	-33%
Rands West Branch	2.48	1.49	-40%
Rands Harbor Total	4.53	2.86	-37%
Fiddlers Main	0.80	0.80	0%
Fiddlers Canal	2.53	1.57	-38%
Fiddlers Cove Total	3.33	2.37	-29%
Combined Total	7.86	5.23	-33%

The above modeling results provide one scenario of achieving the target threshold N concentration and achieving benthic habitat restoration. This example does not represent the only method for achieving this goal. The Town of Falmouth is encouraged to evaluate other load reduction scenarios and take any reasonable steps to reduce the controllable N sources.

Because the vast majority of controllable N load is from individual septic systems for private residences, the CWMP should assess the most cost-effective options for achieving the target threshold N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences. The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the

Clean Water Act Section 208. The appropriateness of any alternative strategies will depend on local conditions and will have to be determined on a case-by-case basis.

Stormwater:
EPA and MassDEP authorized most of the watershed community of Falmouth for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. EPA and MassDEP reissued the MS4 permit in April 2016 and takes effect on March 31, 2017. The NPDES permits issued in Massachusetts do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. Public education and outreach particularly on the proper disposal of pet waste,
2. Public participation/involvement,
3. Illicit discharge detection and elimination,
4. Construction site runoff control,
5. Post construction runoff control, and
6. Pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the Town of Falmouth will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Fiddlers Cove and Rands Harbor systems.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the affected waterbodies of this TMDL can be reopened, if warranted.

The town of Falmouth is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in storm-water runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of storm-water BMPs in addition to reductions in on-site subsurface wastewater disposal system loadings.

It should also be noted that a very small portions of the towns of Bourne and Sandwich are in the headwaters of this system, however, the areas are entirely within the MMR and the developed areas are served by sewers. The development of any implementation plan should also include these towns when coordinating efforts to maximize the reduction in N loading where possible and appropriate.

MassDEP Guidance:
The Massachusetts Estuaries Project: Embayment Restoration and Guidance for Implementation Strategies (MassDEP 2003) (http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/mepmain.pdf) provides N loading reduction strategies that are available to the Town of Falmouth, and that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

* The watershed towns of Falmouth, Bourne and Sandwich are three of the 237 communities in Massachusetts covered (at least in part) by the Phase II storm-water program requirements.

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments maybe needed in the future. The two forms of monitoring include 1) tracking implementation progress as approved in the Falmouth CWMP plan and 2) monitoring water quality and habitat conditions in the estuaries, including but not limited to, the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL report and the MEP Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities, and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by the MassDEP, tracking progress on the agreed upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL values are not fixed, the target threshold N concentrations at the sentinel stations are fixed. Through discussions amongst the MEP partners it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes.

Although more specific details need to be developed on a case-by-case basis MassDEP believes that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations within the down gradient near shore waters of Buzzards Bay as a result of restoration efforts.

The MEP will continue working with the watershed communities to develop and refine monitoring plans that remain consistent with the goals of the TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL through its many permitting programs including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Falmouth has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, storm-water, and runoff (including fertilizers), and to prevent any future degradation of these valuable resources.

Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. Stormwater NPDES permit coverage will address discharges from municipally owned storm-water drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act, Title 5 regulations for on-site subsurface wastewater disposal systems and other local regulations (such as the Town of Rehoboth's stable regulations).

Financial incentives include federal funds available under Sections 319, 604 and 104(b) programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through the Massachusetts Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

As the town implements these TMDLs the loading values (kg/day of N) will be used by MassDEP for guidance for permitting activities and should be used by the community as a management tool.

TMDL Values for Fiddlers Cove and Rands Harbor

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources and non-point sources. A more meaningful way of presenting the loadings data from an implementation perspective is presented in Table 8 and Appendix D.

In this table the N loadings from the atmosphere and sediments are listed separately from the target watershed threshold loads which are composed of natural background N along with locally controllable N from the on-site subsurface wastewater disposal systems, storm-water runoff and fertilizer sources. In the case of the Fiddlers and Rand Estuarine System the TMDLs were calculated by projecting reductions in locally controllable septic systems throughout the entire watershed. Once again the goals of these TMDLs are to achieve the identified target threshold N concentration at the identified sentinel station. The target loads identified in Table 7 represents one alternative-loading scenario to achieve that goal but other scenarios may be possible and approvable as well. It must be demonstrated, however, that any alternative implementation strategies will be protective of the entire embayment system.

Table 8: The Total Maximum Daily Loads (TMDL) for Fiddlers Cove and Rands Harbor

System Component	Target Threshold Watershed Load[1] (kg N/day)	Atmospheric Deposition (kg N/day)	Load from Sediments[2] (kg N/day)	TMDL[3] (kg N/day)
Rands Inlet	0.01	0.02	0.10	0.14
Rands East Branch	1.82	0.03	0.20	2.05
Rands West Branch	2.57	0.09	0.29	2.95
Rands Harbor Total	4.41	0.14	0.58	**5.13**
Fiddlers Main	0.89	0.07	0.86	1.82
Fiddlers Canal	2.48	0.12	0.35	2.94
Fiddlers Cove Total	3.37	0.18	1.21	**4.76**
Combined Total	7.78	0.33	1.79	9.89

[1] Target threshold watershed load (including natural background) is the load from the watershed needed to meet the embayment target threshold nitrogen concentration identified in Table 4.
[2] Projected sediment N loadings obtained by reducing the present benthic flux loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.
[3] Sum of target threshold watershed load, sediment load and atmospheric deposition load.

Public Participation

To be completed after public notice and public meeting held.

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Appendix A: Overview of Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables. This brief summary does not supersede or replace 314 CMR 4.0 Massachusetts Water Quality Standards, the official and legal standards. A complete version of 314 CMR 4.0 Massachusetts Water Quality Standards is available online at http://www.mass.gov/eea/agencies/massdep/water/regulations/314-cmr-4-00-mass-surface-water-quality-standards.html

Applicable Narrative Standards

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(b) states "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)© states, "Nutrients –Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control."

Description of Coastal and Marine Classes and Numeric Dissolved Oxygen Standards

Excerpt from 314 CMR 4.05(4) (a):

(4) Class SA. These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be

suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

4. Dissolved Oxygen. Shall not be less than 6.0 mg/l. Where natural background conditions are lower, DO shall not be less than natural background. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Excerpt from 314 CMR 4.05(4) (b):

(b) Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

4. Dissolved Oxygen. Shall not be less than 5.0 mg/l. Seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. Where natural background conditions are lower, DO shall not be less than natural background.

Waterbodies Not Specifically Designated in 314 CMR 4.06 or the tables to 314 CMR 4.00

Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06 or the tables to 314 CMR 4.00**.** Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (4).

314 CMR 4.06(4):

(4) Other Waters. Unless otherwise designated in 314 CMR 4.06 or unless otherwise listed in the tables to 314 CMR 4.00, other waters are Class B, and presumed High Quality Waters for inland waters and Class SA, and presumed High Quality Waters for coastal and marine waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be made on a case-by-case basis as necessary.

Applicable Antidegradation Provisions

Applicable antidegradation provisions are detailed in 314 CMR 4.04 from which an excerpt is provided:

Excerpt from 314 CMR 4.04:
4.04:Antidegradation Provisions

(4) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and

other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.

(3) Protection of Outstanding Resource Waters. Certain waters are designated for protection under this provision in 314 CMR 4.06. These waters include Class A Public Water Supplies (314 CMR 4.06(1)(d)1.) and their tributaries, certain wetlands as specified in 314 CMR 4.06(2) and other waters as determined by the Department based on their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a Publicly Owned Treatment Works (POTW) unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

4. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited extent specified in 314 CMR 9.00 and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00 but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth

(4) Protection of Special Resource Waters. Certain waters of exceptional significance, such as waters in national or state parks and wildlife refuges, may be designated by the Department in 314 CMR 4.06 as Special Resource Waters (SRWs). The quality of these waters shall be maintained and protected so that no new or increased discharge and no new or increased discharge to a tributary to a SRW that would result in lower water quality in the SRW may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

4. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

4. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. Through 314 CMR 4.04(5)(a)4.

© Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06. Said notice shall state an authorization is under consideration by the Department, and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit.

(d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.

(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized Discharge shall be provided with a level of treatment equal to or exceeding the requirements of the Massachusetts Surface Water Discharge Permit Program (314 CMR 3.00). Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with Permit Procedures (314 CMR 2.00).

Appendix B: Summary of the Nitrogen Concentrations for Fiddlers Cove and Rands Harbor

Town of Falmouth water quality monitoring data, and modeled Nitrogen concentrations for the Fiddlers Cove and Rands Harbor estuary systems (Howes *et. al*, 2013, pg. 96). "Data mean" values are calculated as the average of the entire data set. All concentrations are given in mg/L N.

Embayment	Monitoring Station	Mean	Standard deviation all data	N	Model min	Model max	Model average
Rands Harbor	RH1	0.436	0.092	38	0.326	0.545	0.447
Fiddler's Cove	FC1	0.414	0.098	38	0.356	0.416	0.389

Rands Harbor Annual TN means (2000-2009)

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0.374	0.416	0.423	0.451	0.374	0.382	0.540	0.499	0.544	0.403

Fiddlers Cove Annual TN means (2000-2009)

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
0.335	0.537	0.391	0.493	0.366	0.437	0.388	0.441	0.444	0.322

Appendix C: Stormwater Loading Information

The Fiddlers Cove and Rands Harbor System estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of its waterbodies

System Name	Impervious Area in 200ft buffer (acres)[1]	Total Impervious Area in Watershed (acres)	Total Watershed Area (acres)	% Impervious of Total Watershed Area	Impervious Area in 200ft buffer as Percentage of Total Watershed Impervious Area	MEP Total Unattenuated Watershed Impervious Load (kg/day)[2]	MEP Total Unattenuated Watershed Load (kg/day)	Impervious buffer 200ft WLA (kg/day)[3]	Buffer area WLA as percentage of MEP Total Unattenuated Watershed Load[4]
Rand Harbor	4.6	177.1	1286.4	13.8%	2.6%	0.99	6.81	0.026	0.38%
Fiddlers Cove	15.8	42.3	250.0	16.9%	37.4%	0.22	4.44	0.08	1.87%
Total	20.4	219.4	1536.3	14.3%	20%	1.22	11.26	0.11	1.12%

1- The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.

2- This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, and atmospheric deposition to freshwater waterbodies.

3- The impervious watershed buffer area (acres) divided by total watershed impervious area (acres) then multiplied by total impervious watershed load (kg/day).

4- The impervious watershed buffer area WLA (kg/day) divided by the total watershed load (kg/day) then multiplied by 100.

Appendix D: Fiddlers Cove and Rands Harbor Two Total Nitrogen TMDLs

System Component	Segment ID	Segment Description	TMDL Type	TMDL (kg N/day)
Rands Harbor	MA95-78	harbor south off Megansett Harbor, Falmouth	Restoration	5.13
Fiddlers Cove	MA95-79	cove south off Megansett Harbor, Falmouth	Restoration	4.76